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ABSTRACT

This study examined children's problem solving strategies by testing the verbal and mathematical abilities of 52 second-grade and 51 fourth-grade students. After being identified as either reflective or impulsive, based on Kagan's Matching Familiar Figures Test, the children were given grade-appropriate mathematical and verbal reasoning problems to solve. The children then identified three types of strategies that they had used to solve the problems: (1) external aids, such as pencil and paper; (2) internal reasoning, such as visualizing the problem; and (3) retrieval, the immediate retrieval of an answer without any apparent effort. Results indicated that fourth-graders used a significantly greater proportion of external aids than did second-graders, and that reflective children generally adopted strategies that afforded them high confidence in accuracy, ones using external aids or internal reasoning. Reflective children also demonstrated more accuracy than impulsive children in solving both the math and verbal problems. Boys in both grades were more likely than girls to use internal reasoning on verbal problems, while girls were more likely than boys to use external aids on math problems. Overall, children preferred strategies requiring the most effort, suggesting that they are conservative in their strategy choices. (Contains 23 references.) (MDM)

REFLECTIVITY AND STRATEGY CHOICE IN TWO PROBLEM SOLVING DOMAINS

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Running Head: Reflectivity and Strategy Choice

Abstract

One hundred and three children from the second and fourth grades were identified as reflective or impulsive using Kagan's Matching Familiar Figures Test. They described the strategies they used when solving mathematics and verbal problems that varied in difficulty. The three strategies were 1) use of external aids, 2) internal heuristics, & 3) retrieval. Strategy types varied in average strategy execution time. As expected, cognitive tempo was significantly related to strategy choice. Reflective children generally adopted strategies that afforded them high confidence in accuracy, ones using "external aids" (e.g., paper & pencil), or ones involving some type of "internal heuristic" (e.g.,covertly counting in head). Interestingly, the relationship between confidence, accuracy, and execution time revealed that reflective children were more accurate and confident when using strategies requiring the least effort (e.g., "retrieval strategies"). In general, however, children preferred the more effortful strategies. This suggests that children were conservative when choosing retrieval strategies, a finding previously established by Siegler (1988). In addition, significant age and sex differences were observed. Results suggest that strategy choice is an important factor in the self-regulation of problem solving behavior. Children generally select strategies that they are confident will bring them success. Individual and group differences in strategy choice

reflect differences in ability to successfully estimate problem difficulty and mobilize the appropriate amount of effort to ensure accuracy.

Reflectivity and Strategy Choice in two Problem Solving Domains

Selecting an appropriate problem solving strategy requires an accurate assessment of one's present abilities and relevant knowledge for a given task (Glenberg, Sanocki, Epstein, & Morris, 1987). While efficient problem solvers use self-reflective behaviors to regulate their problem solving efforts (Levine, 1988; Siegler, 1988), there is considerable individual and developmental variation in the ability to do so.

Developmentally, the growth of reflective thought is generally studied in the realm of metacognition (Flavell, 1979). Previous research has documented general increases in reflectivity and metacognitive awareness with age (Flavell, 1979; Kagan & Kogan, 1970). For example, while 7-year-olds begin to engage in performance analysis due to newly developing attentional skills, it is not until the age of 10 years that cognitive evaluation begins to emerge (Brown et al., 1983). Further investigation suggests that even in later years there may be considerable variation in people's ability to monitor their own comprehension and regulate effort accordingly. For example, investigations of comprehension calibration indicate that adults have surprisingly poor insight into their own capabilities, particularly when working problems in an unfamiliar domain (Keren, 1988).

A great deal of research on reflectivity, within an individual difference tradition, has focused on differences in cognitive tempo (Kagan, Roseman, Day, Albert, & Phillips, 1964). Standard measures of cognitive tempo employ analysis of a

subject's response characteristics in regard to both response latency and accuracy on tasks that involve uncertainty (Block & Block, 1974). Theorists concerned with cognitive tempo have often alluded to the "standards" or decision criteria that underlie a pattern of fast-inaccurate responding (impulsive style) as opposed to a slower and usually more accurate pattern of responding (reflective style) (Dickman & Meyer, 1988). In this paper we explore how differences in reflectivity are related to strategy choice on two academic tasks.

The notion that reflectivity might be related to strategy choice is an interesting one, however, it has received little direct research attention. A notable exception is found in a study by Siegler (1988) in which the children were categorized based on their preference for using either more or less effortful strategies. Children identified as "perfectionists" had high task ability, yet relied heavily on time consuming effortful strategies. Siegler hypothesized that these children adopted a very cautious approach and were willing to devote extra time to "feel more confident about their answers." Siegler identified a second group of children who, unlike the perfectionists, were "not so good students" and as such were much less concerned with feeling confident about the answers they reached. Accordingly, these students preferred the least effortful strategies and responded quickly. This response style was associated with less accurate responding than was the perfectionistic style. In his conclusion, Siegler suggested that differences in cognitive tempo may underlie differences in children's preference for more or less effortful strategies.

The primary focus of this paper is to explore how such underlying differences in decision criteria associated with a reflective approach to problem solving might influence strategy choice on academic problem solving tasks in two domains.

Three major hypotheses, with respect to the effect of reflectivity on strategy choice, are explored in this paper. First, we hypothesize that a reflective approach to problem solving predisposes one to engage in constructive processing (Baker, 1985) and comprehension monitoring (Markman, 1979) which generally lead to selection of strategies that more closely conform to task demands than is afforded by an impulsive approach.

Secondly, a reflective approach to problem solving involves a higher standard for task completion and strategy monitoring than does an impulsive approach, as was evidenced by the differences between Siegler's "perfectionists" and "not so good students". We therefore, suggest that reflective children adopt a different default threshold for information processing effort than do impulsive children.

Thirdly, a reflective approach allows one to more accurately assess one's performance (Maki, Foley, Kajer, Thompson & Willert, 1990). We therefore expect reflective children to be more capable of monitoring how their skills conform to task demands. In this final respect we explore solution confidence as a moderator of strategy choice.

Solution confidence is a post-response self-assessment of one's performance. Previous research has explored the role of self-assessments in effort regulation (Bandura & Cervone, 1983;

Nelson-Le Gall, Kratzer, Jones, & DeCooke, 1990). For example, Nelson-Le Gall, Kratzer, Jones & DeCooke (1990) examined how children's ability to assess their own performance motivates use of achievement related help-seeking strategies. These researchers found that the major differences in children's use of help-seeking strategies were due to differences in their ability to use internally based cues for performance evaluation; that is the ability to know when they did not know the solution to a problem and needed to do something about it. In the present study, we similarly hypothesize that differences in the relationship of solution confidence to strategy choice reflect differences in the type of strategic monitoring and regulation different children typically engage in during problem solving.

We hypothesize that the relationship between solution confidence and strategy choice will be different for reflective children and impulsive children. We expect reflective children to be more efficient at selecting strategies that fit their expectations of success.

To explore our hypotheses we pretested 2nd and 4th graders (N =103) on the Matching Familiar Figures Test. Each child was then presented with a series of mathematics and verbal problems that varied in complexity. The children were asked to solve each problem, rate their confidence in the accuracy of their solution, and finally describe the strategies they used when solving the problems. Our analyses focused on the possibility that differences in cognitive tempo (Kagan, 1964), underlie differences in children's metacognitive ability to choose appropriate strategies for efficient problem solving We

specifically compared the strategy choices of reflective and impulsive children on a series of mathematical and verbal problems of varying complexity.

We expected reflective children to spend more time solving problems than impulsive children. In addition, we expected the strategy choices of reflective children to be more directly related to problem complexity, with effortful strategies chosen for the more difficult problems. Finally, we expected the strategy choices of reflective children to be more directly related to their perceived solution confidence than the strategy choices of impulsive children.

In addition, we expected developmental trends in the efficiency of strategy choice selection. We expected our 4th graders to be better equipped than 2nd graders to make strategy choices that reflect accurate estimations of problem complexity.

Finally, we expected significant sex differences in strategy choice. In this respect, three major findings have emerged from a large body of research on sex differences in achievement, particularly in mathematics. First, fairly uniform patterns of results suggest that boys have better math skills than girls (Fennema & Carpenter, 1981; Maccoby & Jacklin, 1974). Secondly, even when they are objectively absent, sex differences are none-the-less perceived by parents and even the girls themselves (Phillips, 1984). Finally, differences in encouragement and feedback from parents and teachers have proven to be important moderators of young girls' achievement related behaviors and beliefs, when assessed by global measures of task and curriculum pursuits (Dweck, Davidson, Nelson, Enna, 1978;). However, little

is known about how differences in strategy choices between boys and girls mediate sex differences in academic achievement. We expect any differences in strategy choices between the two groups will reflect differences in how boys and girls estimate the adequacy of their performance and use these estimates to regulate their problem-solving behavior.

Method

Subjects

Thirty-one male (*M* age = 7.6 years) and 21 female (*M* age = 7.4 yrs) 2nd graders and 16 male (*M* age = 9.4 yrs) and 35 female 4th graders (*M* age = 9.7 years) participated in this study. The participants were ethnically diverse (24% Anglo, 39% African-American, 33% Hispanic, & 4% Other).

Materials

Three testing notebooks were prepared; one contained Kagan's Matching Familiar Figures Test (MFFT; Kagan, 1964) and the others contained either a 12-item block of mathematics problems or a 12-item block of verbal problems.

Mathematical reasoning task. Grade appropriate mathematics problems were presented visually on 3x5 note cards secured in small 3-ringed binders. Each problem had five answer choices (A-E) from which to choose printed directly under the problem. For all problems, answer choice E was always, "I can't find the right answer." This designated the appropriate choice for impossible problems. Each child received four easy problems, four difficult problems, and four impossible problems. Problem difficulty was systematically varied. For 2nd graders, easy problems involved 1-digit numbers being either added or

subtracted, and difficult problems involved 2-digit numbers to which a 1-digit number was either added or subtracted; impossible problems varied in difficulty, but, the correct answer was not offered as a possible choice. For example, 8+3 and 26-4 were easy and difficult 2nd grade math problems, respectively (see Appendix A). For 4th graders, easy problems were two 2-digit numbers being either added or subtracted, and difficult problems consisted of addition or subtraction of 2-digit numbers in which carrying or borrowing was necessary; impossible problems were either easy or difficult but correct answers were not offered as a possible choices. For example, 36-22 and 47+19 were easy and difficult 4th grade math problems, respectively (see Appendix A).

Verbal reasoning task. Grade-appropriate scrambled nouns were presented visually on 3x5 note cards secured in small 3-ringed binders. The nouns were selected from a list of nouns roughly equivalent in standard use (Battig & Montigue, 1969). Presentation of each scrambled noun was proceeded by a taxonomic clue (e.g., "Fruit"). Each scrambled noun had five answer choices (A-E) to choose from printed directly underneath. For all problems, answer choice E was always, "I can't find the right answer." This designated the appropriate choice for impossible problems. Each child received four easy problems, four difficult problems and four impossible problems. Two separate sets of scrambled nouns were created; one for 4th graders and one for 2nd graders. Problem difficulty was systematically varied. For 2nd graders, an easy problem consisted of four letters, a difficulty problem had five letters, and impossible problems were either

easy or difficult but had no appropriate answer choice (see Appendix A for specifics about mathematical and verbal problems).

Procedure and Measures

Testing. Each child was tested individually during one 40-minute session. After children were given the MFFT, they were presented with a first block of 12 problems followed immediately by a second block of 12 problems. The order of the reasoning tasks was counterbalanced across subjects. All subjects received the twelve problems within each reasoning task in the same order. Before presentation of the first problem, the experimenter described the appropriateness of choice "E" (which was always: "I can't find the right answer here") and demonstrated a sample problem. Children were told to take as long as they needed to solve each of the 12 problems correctly. After each problem had been solved, subjects were asked to answer two questions: 1) "Do you think you got the problem right?" and 2) "When solving the problem, what did you do?" The entire session was tape recorded for later transcription.

Cognitive Tempo. Children were identified as relatively reflective or impulsive based on their performance on the MFFT (Kagan, 1964). Standard scoring on the MFFT invariably results in loss of subjects because of the necessity to categorize children for all combinations of errors and latencies (Block & Block, 1974). We combined error and latency scores into a single index, **reflective extent**, using a rationale described by Salkind & Wright (1977). Each child's reflective extent score reflected a combination of median latency on 12 MFFT problems and median

number of errors across 12 trials (i.e., reflective extent = log10(Mlatency) + r * log10(Merrors)). To standardize reflective extent scores, the Pearson correlation coefficient between mean latency and mean errors for each combination of grade and sex was used as a scalar. A median split on the composite reflective extent score was used to identify 50% of children at each age and sex as relatively more reflective than their peers and 50% as relatively less reflective than their peers. A similar heuristic has been usefully demonstrated for combining latency and error scores on skill acquisition tasks (Anderson, 1987).

Strategies on problem solving tasks. Children were asked to describe the strategies they used when solving the problems (Siegler 1988). Three types of strategies were identified:

(a) External Aids - child used an external aid to solve the problem. Examples include writing problem out on paper, counting on fingers, systematically eliminating answer choices, and using touch points (a technique requiring the use of pencil and paper).

(b) Internal Heuristics - child solved problem by using some form of mental heuristic. Examples are counting up or back covertly, counting by twos, and visualizing groups of numbers. A child's answer might be, "I pictured seven apples in my head and then I took two apples away and got five apples."

(c) Retrieval - involved the immediate retrieval of an answer without any apparent effort. A child's answer might be, "I just knew six take away two was four. I memorized it."

Each problem was coded for predominant strategy type. Ninety-four percent of the problems were uniquely identified as strategy types 1, 2 or 3. Six percent of the strategies were

initially coded as mixed because they involved a combination of internal heuristics and external aids. These were later recoded as external aids. Accordingly, the total frequency of three strategy types across subjects and problems was recorded. In addition, each subjects' relative frequency for each strategy type was recorded.

Strategy Execution Time. The amount of time spent on each problem was also coded from the audio tapes. Timing began when subjects were first read the problem and ended when subjects verbally answered or pointed to an answer choice. To avoid inflation due to outliers, each subjects median strategy execution time for each level of problem difficulty was recorded and used as an index of strategy execution time.

Interrater reliability was assessed by re-coding 25% of the original data by independent raters. Blind raters agreed upon 96% of the classification of strategy types and 98% of the recorded strategy execution times (within 1/2 second).

Accuracy and Confidence Measures. In addition to strategy, the experimenter recorded each subject's accuracy and solution confidence on each of the 12 problems. Each student's overall accuracy was recorded as the frequency of correct answers from the total of 12 scores on each reasoning task. For purposes of analysis of variance on proportions, each students overall accuracy was computed from the accuracy on 12 math problems and accuracy on 12 verbal problems divided by a total of 24 total problems.

Children rated their solution confidence on a 3-point confidence scale. Subjects rated confidence as (3) "very sure,"

(2) "maybe" or (1) "unsure." The frequency for each level of solution confidence was recorded across all problems and strategy types. The proportion of "very sure" responses was used as the dependent variable of confidence.

Data Structure and Plan for Analyses. The data was coded, transcribed and structured so as to preserve the conditional relationships of strategy choice, accuracy, and solution confidence on a problem by problem basis. Accordingly, the total data consisted of 24 observations(12 mathematics problems and 12 verbal problems) for each of 103 subjects. The proportion of use for each strategy type, proportion of correct responses, mean strategy execution time and proportion of responses rated as "very sure" (high) confidence was computed for each subject. The mean values were first analyzed using a general linear models of the form: 2(Grade) X 2(Sex) X 2(Cognitive Tempo) X 2(Reasoning task) X 3(Problem complexity) mixed factor analysis of variance. The between factors were grade, sex and cognitive tempo. The within-subjects factors were problem difficulty, and reasoning task. The dependent measures were mean proportion correct, mean proportion "very sure" confidence level, mean strategy execution time and mean proportion use of each of three strategy types. Separate models including a strategy type within-subjects factor were employed when the distribution of strategy use allowed for parametric analysis. A series of non-parametric analyses on the frequencies of accurate responses, and "very sure" confidence responses was used when the unequal distribution of strategy type use made it impossible for inclusion of a within-subjects strategy type factor in the general model (Daniel, 1978). First,

the occurrences of accurate responses, and "very sure" confidence ratings were cross tabulated as a function of strategy used on a problem by problem basis. Next, a series of Chi square analyses were performed on a series of the cross tabulated frequency tables with confidence and accuracy as dependent measures as a function of all between and within factors presented in the general model (SAS Institute Inc., 1988). Significant results were reported in the form of Kruskal-Wallis one way analysis of variance test (an approximation of ANOVA based on Chi square distribution). For each non-parametric analysis, the significant effects were followed up by planned comparisons to confirm mean differences.

Results

Performance on Mathematical and Verbal Reasoning Tasks

Frequencies of strategy use. Summaries of averaged data by between subjects factors and within subjects factors are presented in Table 1 and Table 2 respectively.

Table 1 displays between subjects factors, mean percentage of use, mean percentage of correct responses, mean strategy execution time and mean percentage of 'very sure' confidence ratings as a function of gender, cognitive tempo, grade, and reasoning task.

Table 1 about here

Table 2 presents within-subjects factors, mean percentage of use, mean percentage of correct responses, mean strategy execution time and mean percentage of 'very sure' confidence ratings as a function of strategy type, problem difficulty and reasoning task.

Tables 2 about here

As shown in Table 1, children either employed external aids or internal heuristics on the vast majority of verbal and mathematical reasoning tasks of all difficulty types $X^2(4) = 16.71$, $p < .002$. Surprisingly, there were no significant main effects of cognitive tempo on strategy choice. There was however

a significant effect of grade on strategy use. Fourth graders used a significantly greater proportion of external aids on both mathematical and verbal tasks than did second graders ($F(1,93) = 6.8$, $p < .01$). In addition, there were significant effects of task and problem difficulty on strategy choice. Children were less likely to use internal heuristics on verbal problems (M = 29%) than on mathematical problems (M = 52%). A significant effect of problem difficulty on strategy use revealed that children used a greater percentage of external aids as problems became more difficult (F $(2,186) = 19.76$, $p < .001$).

In addition, there was a significant task X problem difficulty interaction on strategy use, ($F(2, 186) = 23.77$, $p .01$). Bonferroni post hoc comparisons ($p < .05$) revealed that children used a significantly greater percentage of external aids on verbal impossible problems (M = 70%) than on impossible mathematics problems (M = 46%). Interestingly, there was not a single instance of use of retrieval strategies on impossible problems. In addition, a significant grade X task interaction on strategy use revealed that 4th graders were much more likely to employ external aids than 2nd graders, especially on mathematical problems, ($F(2, 186) = 5.34$, $p < .01$). There was also a significant sex X grade interaction on strategy choice (F $(2,186) = 6.53$ $p < .01$). Bonferroni Post hoc tests ($p < .05$) revealed that 4th grade boys used a greater percentage of external aids (M = 74%) than did 2nd graders (M=45%) and 4th grade girls (M = 65%). There was also a significant grade X problem difficulty interaction on strategy choice (F $(2, 186) = 5.56$, $p < .01$). Bonferroni post hoc ($p < .05$) revealed that there was a

significant Sex X task interaction on strategy choice, ($F(2, 186) = 3.05$, $p < .05$). Bonferroni procedures for multiple comparisons ($p < .05$) showed that boys were more likely to use internal heuristics on verbal problems while girls were more likely to use external aids on mathematical problems (Table 2).

Accuracy. The subjects were in general very accurate, averaging 90% correct across all levels of difficulty on both verbal and mathematical reasoning tasks. There were no significant differences in proportion correct as a function of gender or grade. However, there was a significant main effect of cognitive tempo on percent accurate responses. Reflective children were accurate on a significantly greater proportion of both math and verbal problems than impulsive children ($F(1,93) = 6.30$ $p < .01$).

In addition there were significant effects of the within subjects factors of reasoning task, strategy choice, and problem difficulty on proportion correct. The children were significantly more accurate on verbal problems ($M = 96\%$) than on mathematical problems ($M = 84\%$), ($F(1,93) = 15.81$, $p < .001$). There was also a significant task X gender interaction ($F(1,93) = 4.74$, $p < .03$). Bonferroni ($p < .05$) comparisons revealed that girls were more accurate on verbal problems while boys were more accurate on mathematical problems.

A Kruskal-Wallis Anova revealed a significant effect of strategy choice on accuracy ($F(2, 186) = 21.2$, $p < .001$). Post hoc Bonferroni tests ($p < .05$) revealed that children were significantly more accurate when they employed retrieval strategies ($M = 95\%$) than when they employed either external aids

(M = 87%) or internal heuristics (M = 89%). A significant effect of problem difficulty revealed that children were indeed more accurate on easier problems (F (2,186) = 7.57, p <.001). However, a significant grade X problem difficulty interaction revealed that 4th graders were especially influenced by problem difficulty (F (2, 186) = 4.15 p<.01). A significant task X problem difficulty interaction revealed that the differences in difficulty level were much more salient on the mathematics task (F(2,186) = 10.73 p<.001). There was also a significant cognitive tempo X reasoning task interaction (F(2, 186) = 2.97, p < .05). Bonferroni tests (p < .05) revealed that Reflective children were more accurate (M = 96%) than relatively impulsive children (M = 88%) on verbal problems. Bonferroni tests (p < .05) revealed that the differences in Proportion correct were greater on verbal problems than on mathematical problems between reflective children and impulsive children. There was also a significant Task X problem difficulty X grade interaction (F (2,186) = 3.92, p <.02).

Finally, a significant interaction of cognitive tempo X strategy choice that was confirmed by analysis of simple effects on strategy choice revealed that impulsive children were actually more accurate than reflective children when they employed retrieval strategies (F (1,93) = 7.13, p <.01).

Strategy Execution Time. As expected, median strategy execution time was influenced by grade, cognitive tempo, reasoning task, strategy choice, and problem difficulty. A significant grade effect revealed that 4th graders spend a significantly longer time working on problems than did 2nd

graders ($F(1,93) = 6.08$, $p < .01$).

A significant effect of task domain revealed that children spent a longer time attempting to solve mathematical problems ($M = 15.6$ sec) than they did on verbal problems ($M = 10$ sec), ($F(1, 93) = 58.88$, $p < .001$). There was also a significant task X grade interaction ($F(1,93) = 20.99$). Bonferroni post hoc comparisons confirmed that fourth graders spent more time attempting to solve problems than did 2nd graders, but this difference was only significant on mathematical problems ($p < .05$). A significant effect of strategy choice revealed that children took longer to solve problems when they used external aids and internal heuristics than when they used retrieval strategies ($F(2, 186) = 28.8$, $p < .001$).

There was a significant effect of cognitive tempo on strategy execution time. Reflective children spent more time solving problems of all types than impulsive children did, ($F(1,93) = 3.93$, $p < .05$).

A significant problem difficulty effect revealed that children spend more time on the most difficult problems ($F(2, 186)=26.07$ $p < .01$). A significant cognitive tempo X problem difficulty interaction revealed that reflective children, increased the time they devoted to difficult problems. Impulsive children showed no such increase in problem solving effort ($F(2, 186) = 13.44$, $p < .01$). A Kruskal-Wallis test revealed a significant Sex X Strategy choice interaction on strategy execution time ($F(2, 186) = 3.96$, $p <$ 02.). Bonferroni ($p < .05$) showed a sex differences in strategy execution time only on mathematics problems. However, there was a significant sex X

reasoning task interaction ($F(2, 186) = 19.6$, $p < .001$). Bonferroni ($p < .05$) tests of interaction revealed that females spent more time than males solving math problems. A significant effect of problem difficulty revealed that children responded to increases in problem difficulty by increasing the amount of time they used to reach a problem's solution. This generally meant using a higher percentage of internal heuristics and external aids. A significant reasoning task X problem difficulty X gender interaction was found ($F(2,186)=3.66$, $p < .02$). Bonferroni Post hoc tests ($p < .05$) revealed that girls spend more time on impossible math problems than boys.

Confidence. As seen in table 2, significant main effects of grade, sex, cognitive tempo, and strategy choice were observed on solution confidence. A significant effect of grade revealed that second graders reported a confidence level of "very sure" on a greater percentage of problems across all strategies than did 4th graders. In addition, a significant grade X reasoning task interaction revealed that 2nd graders were particularly more confident on mathematical problems than were 4th graders ($F(1,93)=9.95$, $p < .02$). Bonferroni post hoc ($p < .05$) revealed second graders reported "very sure" on an average of 71% of mathematical problems, compared to "very sure" reports on only 59% of math problems by 4th graders. There was also a significant effect of sex on solution confidence ($F(1,93) = 9.24$ $p \leq .03$). Girls reported a confidence level of "very sure" on significantly fewer problems ($M = 60\%$) than did boys ($M = 77\%$).

A significant sex X task interaction revealed that girls reported a significantly lower proportion of 'very sure' than

boys on math only (F (1,93) = 7.27, p < .005). Consistent with the accuracy data, a significant effect of strategy choice revealed that children reported a greater percentage of solutions as "very sure" when they used retrieval and internal heuristics than when they used external aids (F(2,186) = 15.55, p < .02).

Finally, a significant cognitive tempo X strategy choice interaction revealed that, reflective children reported a significantly greater proportion of 'very sure' confidence level but only when they used retrieval strategies (F(1,93) = 3.05, p < .05).

The relationship of strategy execution time and solution confidence was explored further in a regression analysis. Cognitive tempo groups were dummy coded so that they could be included in a general regression equation. Two separate equations one for mathematical and one for the verbal reasoning task were analyzed. In each equation, the median strategy execution time was regressed on confidence, cognitive tempo group and an interaction term. A significant proportion of the variance in median strategy execution time was accounted for by confidence ratings, cognitive tempo, and the interaction (R^2=.10, p <.001; R^2=.05, p <.001; for the mathematical and verbal task respectively). Parameter estimates for the interaction terms in each model were significantly greater than 0 (p's < .05). To explore the nature of the interaction effect more specifically, separate regression equations were created for each cognitive tempo group.

Figure 1 shows the solutions of separate regression

equations when strategy execution time is regressed on confidence ratings by two cognitive tempo groups.

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place figure 1 about here

As shown in Figure 1, a simple effects comparison of the slopes of these separate equations reveals significant differences in how strategy execution time varies as a function of confidence in solution ($z = 3.65$, $p < .001$, and $z = 2.01$, $p < .02$, for mathematics and verbal problems, respectively). While all children rated their confidence as lower on problems that took a lot of time to work, the reflective children were especially likely to judge their solutions correct if they had spent a great deal of time solving the problem.

DISCUSSION

Confidence in solution accuracy appears to be influenced by strategy choice in problem solving situations. Children were generally very accurate on both verbal and mathematical reasoning tasks, although accuracy rates were somewhat higher the verbal problems. Children were generally successful solving both verbal and mathematical problems, however, some individual and group differences were identified. These differences appear to be due to individual beliefs about perceived solution accuracy.

When children used retrieval strategies and internal heuristics they tended to be more accurate than when external aids were necessary; this was especially true for reflective children on the verbal reasoning task. These findings suggest that children do not waste time and effort when they are able to

immediately produce answers that are perceived as being highly accurate.

This conclusion is supported by examination of the relationship between strategy choice and confidence ratings. Children reported themselves as being "very sure" of their answers when they used retrieval strategies and internal heuristics but not so when they needed external aids. Again, some group differences in reported confidence were identified. Girls tended to be less confident than boys. Second graders were more confident than 4th graders across tasks, but especially so on mathematical reasoning tasks. Reflective children were most confident when retrieval strategies were employed.

The importance of solution confidence was again reflected in measures of execution time. Confidence was inversely related to execution time; that is, the longer children took to solve problems the less likely they were to believe that their answers were correct. The mathematics problems, on which children were generally less accurate, were given more time than were verbal problems. Fourth graders, who were generally less confident than their 2nd grade counterparts, also spent significantly more time working math problems. Females, who were less confident than males, also spent more time on mathematical problems.

The different levels of confidence on mathematics and verbal problems makes intuitive sense. All groups were highly accurate on verbal problems, however, all groups appeared to have more difficulty with mathematics problems, as measured by overall accuracy. This suggests that when problems were perceived as difficult, strategy choice differences became more apparent.

In conclusion, patterns of strategy choice, confidence, and accuracy suggest that children were reserving retrieval heuristics for those problems on which they were especially confident. This is consistent with the strategy choice model proposed by Siegler (1988). This appeared especially true for the most reflective children.

In the present study reflective children seemed to more effectively monitor internal signals of uncertainty and regulate their effort based on perceptions of uncertainty in their solution confidence. We suspect that this enhanced regulation led the reflective children to select strategies that were most appropriate for the particular problems they encountered. In this way, reflective children were able to achieve success on difficult problems by increasing effort and to be confident on easier problems while using less effort. Similarly, the older children were able to adjust their effort to task demands more efficiently than were younger children were. Perhaps most interesting were the significant sex effects. G[illegible]s used significantly more external aids than boys, perhaps because they were not as confident in their mathematics ability. This is especially interesting because strategy choice directly reflects differences in confidence standards used by boys and girls. Girls in general were never as confident as boys, even when they were equally accurate on the mathematics problems.

In sum, this study considers reflectivity in its broadest sense, namely, the tendency to engage in metacognitive activity designed to increase efficiency of problem solving. Examining one's initial approach to a problem may provide valuable insight into how individuals estimate their own abilities and attempt to regulate effort for successful problem solving.

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Appendix A

Example of a Second Grade Math Problem

Pick The Best Answer (DIFFICULT PROBLEM)

34

+ 7

a) 5 b) 43 c) 41 d) 31 e) I can't find the right answer

Pick The Best Answer (IMPOSSIBLE PROBLEM)

7

- 2

a) 4 b) 7 c) 2 d) 6 e) I can't find the right answer

Example of a Fourth Grade Math Problem

Pick The Best Answer (DIFFICULT PROBLEM)

187

+ 45

a) 45 b) 323 c) 187 d) 231 e) I can't find the right answer

Pick The Best Answer (IMPOSSIBLE PROBLEM)

123

- 12

a) 12 b) 112 c) 110 d) 123 e) I can't find the right answer

Example of a Second Grade Verbal Problem

A TOY

Pick The Best Answer (IMPOSSIBLE)

O L D L O

a) Doll b) Train c) Ball d) Kite e) I can't find the right answer

Example of a Fourth Grade Verbal Problem

A N I N S E C T

Pick The Best Answer (EASY PROBLEM)

P S I E R D

a) Roach b) Rabbit c) Spider d) Puppy e) I can't find the right

List of Tables

Table 1.

Mathematical Reasoning Tasks

	Boys				Girls			
	Impulsive		Reflective		Impulsive		Reflective	
	2nd	4th	2nd	4th	2nd	4th	2nd	4th
External Aid Use	29 (30.0)	66 (38.9)	18 (27.8)	60 (38.0)	35 (38.4)	59 (38.0)	54 (42.1)	53 (34.4)
Accuracy	82 (40.3)	91 (7.5)	83 (13.6)	97 (7.5)	92 (5.6)	83 (15.1)	87 (15.6)	85 (17.0)
M Time	19 (19.1)	17 (4.2)	20 (11.2)	21 (6.0)	16 (7.6)	17 (5.1)	18 (5.6)	27 (8.9)
Confidence	52 (25.3)	74 (19.4)	53 (32.9)	83 (9.1)	50 (16.4)	48 (9.5)	52 (14.0)	72 (28.9)
Internal Heuristics Use	65 (29.1)	34 (38.9)	72 (26.7)	40 (38.0)	61 (36.2)	40 36.0	40 (38.2)	47 (34.4)
Accuracy	80 (28.3)	85 (3.2)	89 (14.5)	89 (5.0)	67 (28.2)	82 (18.5)	83 (28.9)	86 (12.8)
M Time	10 (5.2)	9 (4.0)	10 (5.2)	9 (3.3)	7 (3.1)	11 (4.9)	8 (3.2)	13 (4.9)
Confidence	62 (16.3)	76 (12.8)	72 (22.4)	52 (3.2)	53 (11.0)	56 (6.1)	72 (29.7)	58 (18.5)
Retrieval Strategies Use	6 (9.5)	0 (00)	9 (8.6)	0 (00)	4 (4.4)	1 (6.1)	5 (10.1)	0 (00)
Accuracy	87 (22)	0 (00)	94 (08)	0 (00)	78 (20)	85 (14)	89 (13)	0 (00)
M Time	1.7 (.35)	0 (00)	6.8 (3.3)	0 (00)	3.3 (2.1)	1.5 (00)	3 (1.9)	0 (00)
Confidence	78 (21)	0 (00)	81 (24)	0 (00)	53 (30)	47 (19)	57 (28)	0 (00)

Note: Numbers in parentheses are standard deviations
M times reported in seconds

Table 1 cont.

Verbal Reasoning Tasks

	Boys				Girls			
	Impulsive		Reflective		Impulsive		Reflective	
	2nd	4th	2nd	4th	2nd	4th	2nd	4th
External Aid								
Use	57 (27.6)	81 (22.2)	43 (26.9)	88 (15.9)	68 (29.5)	72 (29.9)	56 (28.9)	79 (19.8)
Accuracy	88 (23.7)	91 (8.8)	96 (9.1)	91 (12.7)	78 (35.3)	92 (9.0)	99 (15.6)	98 (2.7)
M Time	8 (4.8)	8 (1.7)	12 (7.4)	9 (4.1)	9 (3.4)	17 (3.5)	10 (12.4)	(3.4)
Confidence	59 (22.5)	53 (12.4)	51 (16.1)	67 (18.3)	83 (14.9)	65 (18.0)	44 (7.9)	70 (17.4)
Internal Heuristics								
Use	41 (27.4)	17 (19.4)	51 (25.8)	8 (14.4)	20 (21.9)	20 (30.8)	40 (23.6)	17 (16.5)
Accuracy	87 (21.2)	100 (00)	95 (8.2)	100 (00)	100 (00)	98 (3.2)	100 (00)	93 (13.4)
M Time	8 (3.1)	5 (.4)	6 (2.7)	9 (5.4)	7 (00)	5 (2.0)	5 (1.7)	5 (1.5)
Confidence	50 (11.1)	44 (00)	59 (18.2)	33 (00)	50 (00)	72 (31.4)	57 (13.9)	34 (6.1)
Retrieval Strategies								
Use	2 (6.3)	0 (00)	5 (6.0)	4 (6.6)	13 (19.7)	9 (14.0)	4 (6.8)	4 (7.3)
Accuracy	83 (25)	0 (00)	94 (08)	92 (11)	87 (23)	93 (7)	99.6 (1.5)	99 (03)
M Time	1.1 (.10)	0 (00)	1.2 (.5)	7.8 (3)	2.3 (1.2)	3.4 (2.1)	1.1 (.2)	2.6 (1.5)
Confidence	65 (27)	0 (00)	85 (18)	73 (20)	65 (36)	67 (18)	61 (26)	62 (31)

Note: Numbers in parentheses are standard deviations
M times reported in seconds

Table 2.

	Mathematical Reasoning Tasks			
	Easy	Difficult	Impossible	Total
External Strategies				
Percent Use	39 (38.9)	48 (42.8)	46 (38.7)	44 (40.1)
Percent Accuracy	96 (16.7)	79 (34.2)	84 (27.3)	86 (26.1)
M time	16 (11.6)	22 (13.5)	21 (10.4)	20 (11.8)
% Hi Confidence	57 (26.0)	60 (28.4)	43 (25.3)	53 (26.6)
Internal Heuristics				
Percent Use	54 (37.9)	50 (41.8)	51 (37.0)	52 (38.9)
Percent Accuracy	88 (27.2)	80 (32.4)	80 (28.9)	83 (29.5)
M time	9 (5.1)	11 (8.5)	11 (4.7)	10 (6.1)
% Hi Confidence	61 (23.2)	63 (23.8)	48 (26.4)	57 (24.5)
Retrieval Strategies				
Percent Use	7 (15.6)	2 (9.2)	00 (00)	5 (12.4)
Percent Accuracy	88 (33.2)	80 (44.7)	00 (00)	84 (39.0)
M time (in seconds)	5 (3.3)	6 (5.3)	00 (00)	6 (4.3)
Rated Confidence	38 (12.7)	40 (14.1)	00 (00)	39 (13.4)

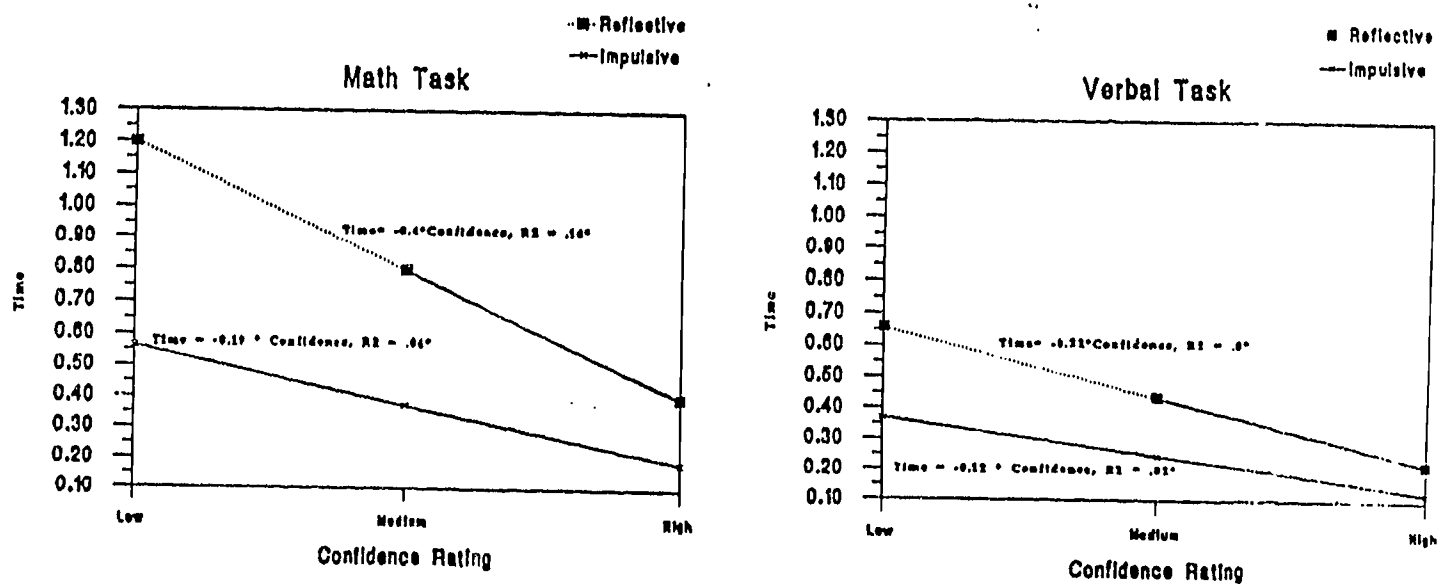
Table 2. cont.

Verbal Reasoning Tasks

	Easy	Difficult	Impossible	Total
External Strategies				
Percent Use	60 (32.4)	65 (35.6)	70 (30.2)	65 (32.7)
Percent Accuracy	94 (20.9)	95 (19.6)	88 (21.5)	92 (20.7)
M time	9 (5.0)	12 (11.1)	10 (5.3)	10 (7.1)
% Hi Confidence	60 (23.0)	60 (25.4)	58 (26.6)	59 (25.0)
Internal Heuristics				
Percent Use	32 (30.4)	30 (34.6)	26 (29.1)	29 (31.4)
Percent Accuracy	94 (20.4)	98 (9.4)	95 (16.6)	96 (15.5)
M time	6 (4.2)	7 (4.0)	7 (5.9)	7 (4.7)
% Hi Confidence	45 (19.6)	50 (23.0)	35 (20.3)	43 (21.0)
Retrieval Strategies				
Percent Use	8 (17.1)	5 (13.7)	00 (00)	7 (15.4)
Percent Accuracy	98 (11.2)	100 (0)	00 (00)	99 (5.6)
M time	3 (2.7)	2 (1.4)	00 (00)	3 (2.1)
% Hi Confidence	38 (11.7)	40 (13.6)	00 (00)	39 (12.7)

Figure 1: Regression of Time on Confidence Ratings for Reflective and Impulsive Children

*p < .01



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